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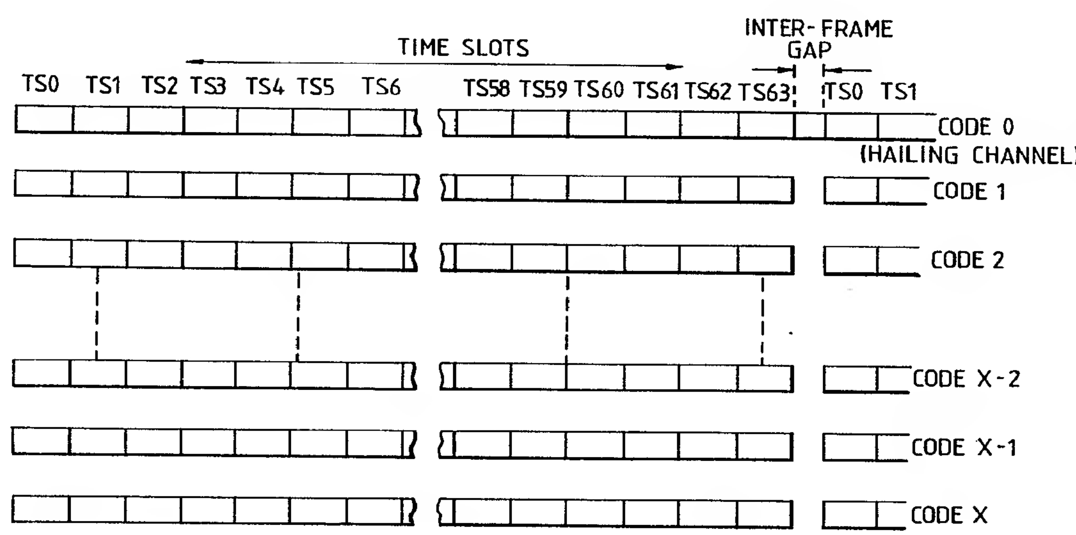

(57) Abstract

A communication system includes channels for communication between subscribers defined by the combination of a selected CDMA code and a selected one or more time slots within a TDMA frame. The system may include a number of subscribers (2) connected via a common transmission medium to an access node (1). In this case the access node (1) is arranged to assign the channels to the subscribers during an access phase. The node (1) may communicate with the different subscribers on a common hailing channel. In one example, the hailing channel is defined by a pilot CDMA code common to the node (1) and to the subscribers (2). As well as allocating channels, the node (1) may select an appropriate data format and transmit indications to the subscribers of the data format selected.

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CDMA/TDMA COMMUNICATION SYSTEM

The present invention relates to data communication systems and in particular to a novel access protocol for the transmission of data over a common channel. The invention is of relevance to all types of shared transmission media such as wire transmission lines or optical fibres but is particularly appropriate to digital radio networks.

In communication networks using a shared channel, signal multiplexing is adopted to enable multiple subscribers to make use of the channel. Connections which may be used by subscribers are distributed along the common channel thereby allowing multiple access. An access protocol determines the conditions under which a given subscriber can transmit or receive data from the channel. This combination of multiple-access, signal multiplexing and the access protocol enables subscribers to communicate via their own "virtual physical link" which is set up during an initial access phase.

As described in further detail below, hitherto two main techniques have been adopted for multiplexing data in multiple access systems. In "time division multiple access" or TDMA, data is transmitted in frames divided into a number of time slots of equal duration. Each data transmission from a given subscriber is allocated its own time slot within the time frame. The transmission from each subscriber therefore cannot be continuous, but is sampled and as many bits as can be fitted within the slot are transmitted in a given frame. The maximum number of different transmissions which can take place within a given time frame is set by the number of slots in the frame. TDMA systems therefore require a very rigid protocol.

An alternative prior art technique is code division multiple access or CDMA. This relies on coding each data

transmission with a unique pseudo-random code which is modulated on the data before the data is modulated onto the carrier. In the receiver, the data is recovered by correlating the code modulated data with a replica of the code used in the transmitter. Different virtual physical links can be accommodated by coding the relevant data transmission with different codes from the same basic family of codes. The code normally has a bit rate considerably higher than that of the data so that the transmission bandwidth of the modulated data is very much wider than that of the raw data. Such techniques are therefore referred to as direct-sequence spread-spectrum modulation.

Conventional CDMA systems suffer a number of disadvantages. Unlike TDMA systems, each received signal is always corrupted by spread-spectrum cross-talk from other CDMA transmissions. A further limitation is the need to provide a unique code for every subscriber connected to the network.

According to a first aspect of the present invention, there is provided a communication system in which subscribers connected to the system communicate on channels defined by the combination of a selected direct sequence CDMA code and a selected one or more time slots within a TDMA frame.

The present inventors have developed a new multiplexing technique which they have termed "multiple division multiple access" or MDMA. This novel technique draws upon aspects of TDMA and direct sequence CDMA in combination to provide a system which is superior in performance to either of those techniques used on their own.

In particular, MDMA provides a greatly improved response to a temporary overload of the system since the number of CDMA channels can be increased beyond the normal operational limits at the cost only of an increase in the level of noise. In a pure TDMA system by contrast there is

an absolute limit to the number of transmissions set by the number of time slots per time frame. At the same time the use within MDMA of multiple time slots removes the need to provide a unique code for each subscriber so that this system can function with a much smaller code set. In addition, through the use of direct sequence coding, the system enjoys good broadband noise rejection.

Preferably the system comprises a plurality of subscribers connected via a common transmission medium to an access node arranged to assign the virtual physical links, hereinafter referred to as MDMA channels, to the subscribers during an access phase.

The present inventors have developed a protocol and a network architecture embodying that protocol which maximises the benefits available from MDMA. One important feature of this protocol is the use of nodes to assign dynamically MDMA channels to the subscribers thereby ensuring maximum efficiency in the use of the slots available on the network and avoiding the need to have a unique code for each subscriber.

Preferably the access node is arranged to communicate with the different subscribers on a common hailing channel. Preferably the hailing channel is defined by a pilot CDMA code common to the node and to the subscribers.

The use of a dedicated hailing channel is another major aspect of the present invention. It is not limited in applicability to direct sequence codes but can also be used with frequency hopped codes. The frame structure of the hailing channel is identical to the frame structure of all other CDMA channels and the use of this channel for hailing may be restricted to a specific time slot so that excess capacity is not wasted on synchronisation and network management functions.

The frame structure consists of a number of contiguous time slots followed by a guard-band period which acts as an end-of-frame marker. There are no transmissions in this guard-band period except for the hailing channel which can

send synchronisation information during this period for the subscriber equipment to achieve chip and frame synchronisation. All subscribers re-synchronise to the pilot code on the hailing channel during this inter-frame gap but run free during the rest of the frame period. Having identified the start of this frame, all subscribers then transmit in their allocated time-slot, which is received by the access node after a propagation delay. To overcome this delay problem, the inter-frame gap provides an opportunity for the base-station access node to assess the propagation delay between it and the outlying subscribers so that correct frame synchronisation can be achieved using the method of delay management. In this method, specific data patterns are sent to the base-station from a particular subscriber device, at the base-station's request, and the transmission of the pattern is progressively advanced by the subscriber device until the pattern is correctly detected by the access node. The access node then indicates to the subscriber that the pattern has been received correctly, and the subscriber equipment stores the relative phase advance that is necessary to exactly counter the propagation delay and this is used in conjunction with the inter-frame gap to ensure that all transmissions from the subscribers are correctly synchronised when received by the access node.

The use of a pilot code as an access or hailing channel enables the system of the present invention to run in a synchronised mode and from this information precise timing information for the time frame and time slot synchronisation can be obtained.

Preferably in the access phase, after the node has communicated with a transmitting subscriber and a receiving subscriber on the common hailing channel the node selects a free MDMA channel defined by a CDMA code other than the pilot code and a selected one or more time slots and transmits to the transmitting subscriber and the receiving subscriber an indication of the selected channel, the

subscribers subsequently communicating via the node on the selected channel.

Preferably the node is arranged to communicate in addition data indicating a selected data format for the transmissions between the subscribers, the said data indicating whether the MDMA channel includes single or multiple time slots within each frame, and where multiple time slots are used whether those slots are contiguous or time disjoint.

A further important advantage of the present invention is that it makes it possible to adapt dynamically the format adopted for data transmission according to the nature of the traffic to be carried. In particular for high bit-rate traffic multiple time slots may be allocated to the MDMA channel.

Preferably when the allocated channel includes a plurality of contiguous time slots then the data format is adapted by removing redundant header and or trailer bits from the second or subsequent slots, and using the corresponding bit positions for traffic data.

This technique of adapting the MDMA channels by assigning single or multiple time slots according to the requirements of the traffic, and varying the data slot structure when contiguous slots are used for one channel may also with advantage be used in otherwise conventional TDMA systems, and is not limited in application to the MDMA system of the first aspect of this invention.

Preferably the communication system is a digital radio network.

The present invention has particular advantages when applied to a digital radio network, although as noted above it may also be applied to other media such as wire cable or optical fibre networks.

The present invention also encompasses subscriber equipment, such as a digital radio telephone adapted for use in a network employing the MDMA protocol.

One example of a system in accordance with the present invention will now be described in detail and contrasted with the prior art with reference to the accompanying drawings, in which:

Figure 1 is a schematic showing the architecture of one example of a network suitable for use in the present invention;

Figures 2a and 2b are diagrams illustrating multiple access and star networks respectively;

Figures 3a to 3c are diagrams illustrating time division multiplexing;

Figures 4a and 4b are diagrams illustrating code division multiplexing;

Figure 5 is a diagram illustrating a typical frame structure providing time slots of 16kb/s data or digitised speech signals;

Figure 6 is a block diagram of a digital radio telephone; and

Figure 7 is a block diagram of an access node.

Figure 1 shows a schematic of the overall system architecture to which this example of the present invention is applied. A number of subscribers are connected in common to an access node 1. Each subscriber uses an interface device called a subscriber access device 2 (or SAD) which allows access to the physical network by the appropriate data terminal equipment 3 (DTE) which is connected on the subscribers side of the SAD. In the present example, all the subscribers are connected to the network via the medium of radio transmission and the common air interface is a radio transceiver. The access node 1 acts as a switch to route the information flow between the subscribers and also acts as the network controller.

Figure 6 is a block diagram of the radio telephone incorporating the MDMA SAD of the present example. The telephone might be used for voice telephony, or, for example, for providing a data link for a personal computer using a modem. The radio telephone incorporates a

smartcard interface 61, a keypad 62, a control processor and associated ROM 64. The control processor 63 is linked to an MDMA coder 65. The coder encodes data from a data source 66. Typically the data source will represent a speech signal. The encoded data is output via an RF stage 67.

Subscribers may also send or receive information to another similar network via the access node, which routes the information through a conventional transmission network such as a dedicated broadband link 4 (optical fibre or microwave link) to the access node of the other network. Furthermore, it is possible for subscribers to access other types of broadband service available on the ISDN network 6 via the access node which can also route signals via a broadband link 7 to an asynchronous transfer mode (ATM) switch. The mode of operation of the network is "full duplex" which is accomplished by allocating two physical channels for the two different directions of transmission. In the case of the radio network, this is achieved by allocating two frequency channels, one for the up-link and one for the down-link.

The network is equivalent to a star network but uses shared transmission media rather than many separate wires (Figures 2a and 2b).

The main purpose of this radio network is to allow the network subscribers to have access to a range of digital information services, such as digitized voice, fax, data, video and public utility telemetry etc. which are either currently available or have been proposed for the integrated services digital networks (ISDN). The appropriate terminal equipment must be connected to the SAD via terminal ports, of course, but it is necessary for the SAD to be transparent to these various communication services. The SAD not only acts as the interface device, but also as a switch. A feature of the access protocol is that it uses common channel signalling to directly control the switching function of the SAD to enable the information

to be routed through the SAD to the appropriate terminal port on the SAD.

The configuration of the SAD is also directly controlled by the proposed new access protocol via common channel signalling in the sense that it can adapt, dynamically, to different data formats in a way which optimizes the overall throughput of the system. However, the main requirement of the SAD is to gain, control and maintain access to the network by the subscriber according to the overall network access protocol.

Figure 7 shows the construction of the access node 1. The diagram is applicable to both direct-sequence and frequency hopped access nodes. The access node of the direct-sequence spread-spectrum system transmits and receives m x n burst-mode signals simultaneously. The transmitted signals are transmitted at a frequency f_t and the received signals are received at a frequency f_r. The two bands of frequencies occupied by transmitted and received signals do not overlap. Each burst lasts for the duration of one time slot (or a multiple thereof) and there are n time slots per frame. Additionally, m simultaneous TDMA data streams may be transmitted, each being coded by a different CDMA code.

The antenna is common to both transmit and receive sections of the base station by means of a duplexer, in the normal way. The receiver r.f. section 101 is a conventional broadband linear amplifier and filter unit to provide the required sensitivity and to reject adjacent channel interference. The r.f. section is translated to an intermediate frequency (i.f.), using one or several frequency conversion steps, in the normal way. In the i.f. section 102, additional filtering takes place and the signal is then demodulated to produce the required baseband signal comprising m CDMA messages. The demodulation process is the inverse of the modulation process. If the transmitter uses QPSK modulation the receiver uses a QPSK demodulator, etc. The modulator 104 and demodulator 105

use standard r.f. and i.f. technology and the method of implementation is well understood.

In the synchronisation unit 106 a bank of m synchronisers in parallel establish chip, code and frame synchronisation for each of the CDMA channels and this synchronisation information is passed to the code correlator 103 and the TDMA demultiplexer 104. Conventional CDMA code synchronisers such as serial search synchronisers and delay lock loop synchronisation tracking units may be used, as in the SAD. However, in the base-station m such units would be required, one per CDMA code. Time slot synchronisation is facilitated by the frame structure which is being adopted. This incorporates a time frame marker on the hailing channel, as described above.

Also at the i.f. output, a bank of m code correlators 103 or matched filters despread the m CDMA channels in parallel. These m channels each contain n messages via TDMA multiplexing and these are demultiplexed in the next unit 104 which contains m TDMA demultiplexers in parallel.

The n x m messages are put into an appropriate format prior to transmission onto the network via the base-station/network interface 107, described in the figure as an ATM/TDMA interface (ATM = asynchronous transfer mode) or SDH/TDMA interface (SDH = synchronous digital hierarchy). This interface also interrogates the received data to establish whether it is data for transmission onto the main network or whether it contains control information for use by the base-station. Such information may be the messages needed to set up a call, according to the media access protocol described above.

The signal from the correlator output is also fed to a power control unit 108. This unit contains n x m power control circuits in parallel, one for each burst message. The purpose of the power control circuit is to ensure that the power of each burst transmission is received at the base-station at a given signal level, and that the average power of each CDMA channel is the same. The power control

unit compares the actual power level from all m correlators at all the n time slots against a reference value. The output of the power control unit is n x m digital words per time frame representing the power level error information of each message. This error information is transmitted back to the appropriate SADs by coding the error information into the headers of the packets of data being transmitted during each time slot. Power control of the received signals is necessary for direct-sequence spread-spectrum systems for optimum performance.

In the transmitter unit, the ATM/TDMA or SDH/TDMA interface 107, which will invariably be a microprocessor based unit, receives the data from the network and interprets the information as either data to be transmitted over the MDMA radio link or network control information, in the normal way. The data to be transmitted over the link is assigned a virtual channel in the form of a unique time slot and a CDMA code. This interface unit re-packetises the data according to the MDMA protocol inserting additional information such as synchronisation bits, frame header and trailer bits, power control bits and network signalling bits.

This packetised data is then routed to the TDMA multiplexer 105 appropriate to its CDMA code and transmitted during the appropriate time slot.

The streams of data from the m TDMA multiplexers is then spread in frequency by the CDMA multiplexers 109 and the m CDMA streams combined linearly to form a single complex waveform.

This signal is transmitted at the appropriate carrier frequency using the appropriate method of modulation such as double sideband suppressed carrier. Alternatively, as shown, each CDMA code can be separately modulated onto the carrier and the linear combining carried out at r.f. rather than baseband. This later approach is more hardware intensive but more spectrally efficient.

Frequency Hopped CDMA System

The basic structure of the frequency hopped access node system is generally similar to that of the direct-sequence system. The access node would transmit on a band of frequencies centred at f_t and receive on a bank of frequencies centred at f_r. The two bands of frequencies do not overlap. The ATM or SDH interface and the TDMA aspects of the access node are identical to the direct-sequence case.

Considering the transmitter section, the m TDMA data streams are fed to the frequency hopped CDMA modulators in place of the direct-sequence CDMA modulators. Here, each TDMA data stream is transmitted on a unique carrier frequency. The frequency of each of the m carrier signals changes periodically, and in such a way that two or more TDMA data streams are never transmitted on the same carrier frequency. The method of modulation of the TDMA data stream onto the hopping carrier is by any spectrally efficient method, such as QPSK or MSK, but this is not central to the patent.

In the receiver, the r.f. section is the same as for the direct-sequence case, but the i.f. section and the code correlators have a slightly different structure. In the frequency hopped receiver, each of the m correlators is replaced by a coherent demodulator. This comprises of a local oscillator signal which is hopping in perfect synchronisation to the transmitted signal such that the i.f. frequency is always constant. An appropriate demodulator then demodulates the resulting i.f. signal, which results in a TDMA data stream. m such local oscillators and demodulators provide the m TDMA data streams, which are demultiplexed as for the direct-sequence case.

Code synchronisation is required as for the direct-sequence case, but this type of technology is now well understood.

The access node controls the operation of the shared channel on the basis of information supplied to it from each subscriber. This is also supplied via the access protocol. The access protocol to be described has four main layers. Even so, the access protocol may be assumed to operate at the lowest levels of the overall (end-to-end) protocol used by an application since it represents the transmission of the raw data at the bit level. For example, if the network allows a subscriber to transmit packetised data, the subscriber's own DTE would provide the necessary data link protocol to initiate packet retransmission etc., and the system is transparent to the format of the data. A feature of the proposed access protocol is that it is configurable to allow a great many different data link protocols to be handled by the MDMA network as well as a wide range of data formats including voice, data and video information as well as data transmission to the X.25 standard. For certain types of data transmission which currently use voice channel modems, e.g. the following data link protocols: V21, V22, V22bis, V23 etc. the access protocol is completely transparent. The various layers of the protocol are described in entirely general terms in the following sections. More detailed descriptions of the operation will be given in a subsequent section. It is assumed that transmissions from each SAD to the access node takes place on the "up-link" channel of the full duplex link, and transmissions from the access node to each SAD takes place on the "down-link" channel.

Subscriber-Connect Protocol

The first layer represents the subscriber-connect protocol. This is the first phase of connection of a subscriber onto the network and takes place whenever the SAD is powered-up and programmed or whenever it is reprogrammed. It essentially logs a new subscriber onto the network. The SAD has to be programmed with the relevant information regarding the subscriber, and this can

be accomplished using a "smartcard". For most practical purposes, the relevant information required is the subscriber identification number, although other status information may also be provided. This information must be passed to the access node to indicate that the subscriber is physically connected to the network. This information is then logged by the access node's database as an active SAD. The access node also carries information regarding active SADs in other similar networks.

The smartcard removes the restrictions inherent in conventional telephone systems, whereby the telephone number is associated with the physical location of the telephone handset. In this system a subscriber may reprogram any SAD to receive calls. Billing is attributed to the subscriber identification number not the physical location of the SAD. Whilst the smartcard is in the SAD, the SAD remains logged on to the network. When the smartcard is removed, the subscriber-connect protocol automatically informs the access node that the SAD has become inactive. The SAD must then be reprogrammed with a smartcard before further network access can take place.

Media Access Protocol

This second layer of protocol is transmitted whenever the "logged-on" subscriber wishes to access the channel to transmit information. In this case the protocol is in the form of a handshake protocol. The first handshake is between the transmitting SAD and the access node and the second handshake is between the access node and the receiving SAD. Both handshakes have to be set up before transmission can begin. The SAD requesting access to the network for transmission of data sends its identification number to the access node together with the identification number of the SAD requested to receive the data and also information regarding the requirements of the transmitted signal (i.e. the required data rate and the data format). This acts as a request for access. With this information, the access node is able to calculate whether there is

available capacity on the network. The access node also ascertains whether the requested receiving SAD is connected (i.e. logged-on the network) or if it is currently engaged. If any of these events occur the access node does not complete the handshake and terminates the access with an appropriate message detailing the reason for non-connection. If the receiving SAD is able to receive information, the handshake is set up. This is accomplished by the access node sending an acknowledgement to both sending and receiving SADs. At this point, further information is passed to both the transmitting SAD and the receiving SAD which enables them both physically to gain access to the channel. Although this information is strictly part of the media access protocol, it defines the parameters needed for the third layer of the access protocol, the data multiplexing protocol.

Data Multiplexing Protocol

The "further information" referred to in the previous section is in three parts. The first piece of information concerns synchronization information which is passed to both the transmitting and receiving SADs regarding the precise time slot within the time frame that the SAD may transmit. This process is broadly similar to Time Division Multiple Access multiplexing (TDMA) but differs in many important details, detailed below.

The second piece of information concerns the format of the data from the DTE connected to the transmitting SAD. If the requirement is for a very high data rate, this can only be achieved by occupying several time slots within the time frame. This second layer of the data multiplexing protocol is entirely unique in that it optimizes the allocation of multiple time slots. It works in the following way. Depending upon the current allocation of time slots by the access node to other SADs already accessing the channel, the necessary multiple time slots made available to the SADs by the access node may be time contiguous or time disjoint. The information regarding the

distribution of the time slots is passed onto a fourth layer of the access protocol called the "data protocol". This is different from the data link protocol used by the DTE.

The third piece of information consists of the passing of an "address" to a unique code which is stored in both transmitting and receiving SADs. Once the SADs have received this code, the transmitting SAD uses it to multiplex the data (which, it will be recalled, is restricted to occupying a specific time slot within the time frame) onto the channel and the receiving SAD uses the same code generated locally to demultiplex the data from the channel. This method of multiplexing is similar to Code Division Multiple Access (CDMA). This method of multiplexing will be detailed below. These two methods of multiplexing (TDMA and CDMA) are combined in a unique way to represent the method by which the information is able to share the common transmission medium. The maximum number of users able to access the channel is simply the product of the number of time slots per time frame and the number of CDMA channels. Each user may be regarded as transmitting over a dedicated MDMA channel.

<u>Data Protocol</u>

The transmitting SAD encodes the source data from the DTE with synchronization, header and trailer information each time data is transmitted during a time slot. This is the data protocol, as far as the multi-access system is concerned but this information is redundant as far as the DTE is concerned and is removed at the receiving end by the SAD prior to being routed to the appropriate DTE. When the media access protocol indicates time contiguous slots, the data protocol is adapted so that the synchronization, header and trailer information is only sent once. This removes unnecessary protocol overhead and further, it allows the time guard-band, which is used to prevent data collisions, to be used to transmit data. In this way it

will be seen that the new access protocol is extremely powerful in optimizing the flow of data along the channel.

Data Link Protocol

The various layers of the access protocol work at a level below the actual data link protocol used by the DTE. These data link protocols are assumed to be to the standards currently adopted for the various services proposed for the Integrated Services Digital Network (ISDN) for voice and data, listed in table 1 and the current and future data link protocols for digital video transmission such as CCITT standards px64 including H.261, H221, G.722 and G711 proposed for the broadband ISDN. For voice modem data transmission such as V21, V22 and V23 and group 3 fax transmission, the access protocol is completely transparent to the data link protocol.

The foregoing has identified a number of areas on which this invention has drawn. One is the area of time division multiple access, referred to as TDMA (or time division multiplexing, TDM). A second is code division multiple access, referred to as CDMA. A third area of relevant background art is the media access protocol used in digital mobile radio applications.

Time Division Multiplexing. In this method, time is divided into time slots of equal duration. X consecutive time slots comprise a time frame. Within each slot period Y bits may be transmitted. Each data transmission is allocated its own time slot within the time frame, and so each transmission cannot be continuous for all time, but is sampled and Y bits of the sampled signal are transmitted during the appropriate time slot. Consequently, a maximum of X different sampled transmissions can take place within the time frame. The TDMA protocol is very rigid. Each transmission occupies one time slot, and that time slot must be synchronized to occur at the same time within the frame. Each time slot is specific to one user and cannot be reallocated to another user. The limitations on X are dependent on the maximum sampling period that may be

tolerated before the fidelity of the original signal is seriously impaired (this sets the maximum frame period), the bandwidth of the transmission channel (which sets the maximum bit rate), and Y (which sets the minimum slot period). Thus if the maximum sampling period for a particular application is 125μs and the channel bandwidth is 1 MHz indicating a maximum bit rate of about 1Mb/s, the total number of subscribers sharing the channel is 12.5 if 10 bits per time slot are used. Figure 3a illustrates the process of time division multiplexing.

Multiple access capability is possible either by routing the messages to the appropriate subscribers directly at the end nodes of the shared channel, which are the multiplexer/demultiplexers DM, as shown in Figure 3b, or by drop-in multiplexer/demultiplexers along the channel, as shown in Figure 3c. In this case each drop-in demultiplexer is synchronized to add or recover data at a given slot time within the frame period.

There are a number of drawbacks with conventional TDMA. The first is that the maximum number of users on the network is quantified at the outset and it is not possible temporarily to overload the system. The second is that if the total number of users at any time is less than the maximum X the time frame is not used very effectively, and there are periods when no data is being transmitted, even though it would be more efficient for other users to extend their transmission period to take account of the missing users. It will be seen that the preferred example of the present invention has a much more sophisticated and powerful protocol which allows random allocation of time slots to individual transmissions, dynamic reallocation of time slots to other users and multiple time slot allocation.

<u>Code Division Multiple Access</u>. There are two main types of CDMA multiplexing technique. One method is called direct-sequence CDMA and the other is called frequency hopped CDMA. The direct sequence CDMA method of multiplexing

relies on coding each data transmission with a unique pseudo-random code of length L chips. This is done by modulation of the code onto the data prior to modulation onto the carrier. This is shown in figure 4a for arbitrary modulation of the coded data bits onto the radio frequency carrier.

In the receiver the data is recovered by correlating the code modulated data by a phase and epoch synchronized replica of the code used in the transmitter. In this way, the wanted data is extracted from the code, as shown in Figure 4b. If there is a phase difference between the received signal and the local code replica, the amplitude of the recovered signal can be very small if the phase error is large. This is dictated by the autocorrelation function of the code. Other data transmissions can be accommodated on the channel by coding them with different codes from the same basic family of codes (e.g. maximal length codes, Kasami codes or Gold codes) and of the same length L.

All these simultaneous transmissions occupy the same frequency channel and are detected by every receiver sharing the channel. However each receiver rejects all the signals bar the wanted transmission to a degree determined by the cross-correlation between the code and all the other codes used in the multiple co-channel transmissions. Ideally the cross-correlation function should be zero. For most codes currently used in practice, the cross-correlation function is not zero because the codes are not perfectly orthogonal, and the result of this is cross-correlation "noise" or cross-talk from the other user(s) appearing on the wanted signal. The penalty of CDMA is that the output SNR is always limited by the other CDMA transmissions and as the number of transmission is allowed to increase so too does the level of noise on each detected signal. Interfering signals, such as noise, accidental or intentional jamming and any other signals which do not have a high degree of correlation with the local code can also

be rejected in the same way as the CDMA channels and this gives the technique immense advantages over other orthogonal multiplexing techniques such as TDMA when the system is interference limited, as is common in many radio area-coverage schemes.

This ability to demultiplex a wanted transmission from many other co-channel transmissions or to reject interference does not stem purely from the coding strategy however, but by the fact that the code is clocked at a much higher rate than the data to ensure that during the correlation process each data bit can be detected by integration over the code repetition period. To achieve this, the code rate is usually at least L times higher than the data rate. This high speed code has a wide bandwidth and consequently the transmission bandwidth of the data modulated code is very much wider than the data bandwidth. This technique is referred to as direct-sequence spread-spectrum modulation.

The normal method of encoding the data with the pseudo-noise code is to use digital modulo 2 addition using an exclusive OR gate. For radio networks, this encoded data stream is then modulated onto the rf carrier in the normal way using either binary phase shift keying quadrature phase shift keying or minimum shift keying. The method of modulation onto the carrier is not a key feature of this patent application.

Frequency hopped CDMA also uses pseudo-random codes, but in this case the value of a pseudo random n-tuple word is used to control the carrier frequency of the data transmission. The data may be modulated onto the carrier using any conventional technique, such as Frequency Shift Keying or Phase Shift Keying etc. As the value of the pseudo-random word changes, so too does the carrier frequency. In this way, each message hops from frequency to frequency at the same rate as the pseudo-random code is clocked by the system and the pseudo-random codes are chosen such that the likelihood of two messages

simultaneously being transmitting on the same frequency is very low. Consequently, this too is a multiple access multiplexing technique in which all the messages share the same frequency band. However, unlike direct-sequence CDMA, the various messages do not occupy all the frequency band simultaneously, but only small parts of it for the duration of each hop.

The frequency hopping receiver also uses a form of correlation to recover the messages being transmitted. The receiver uses the same pseudo-random code pattern as the transmitter and is phase and epoch synchronised to it. Each code word represents either the same carrier frequency as in the transmitter or is offset from the transmitter frequency by a fixed amount (the intermediate frequency). Thus, when the transmitter frequency changes it is tracked exactly by a change in the local oscillator frequency in the receiver and the message is always translated to a single intermediate frequency where it can be demodulated in the normal way.

In the present specification "CDMA" is used generally to denote both direct sequence and frequency hopped CDMA, except where indicated to the contrary.

In the conventional CDMA system, each user transmits simultaneously and time contiguously (compared with the case of the TDMA system). The penalty, relative to the TDMA systems is that each received signal is always corrupted by spread-spectrum cross-talk from other CDMA transmissions, where for an ideal TDMA system under jitter free conditions, there is no corruption of the demultiplexed signal through cross-talk.

A major problem with the conventional CDMA multiple access protocol is that every subscriber on the network is allocated a unique code, which forms the address of that subscriber. For large networks, this requires the existence of a code set with a very large family of codes of excellent auto- and cross-correlation performance. A considerable effort has been expended in recent years in

attempting to find classes of code which meet these three criteria. For most real networks, however, the number of subscribers requiring simultaneous access to network is considerably less than the total number of subscribers.

The new access protocol removes the requirement that the code should act as the address of the subscriber and this immediately removes the requirement for large families of codes.

It will be apparent that although both TDMA and CDMA methods of multiplexing are synchronous, the method of operating their respective networks is totally different. CDMA is excellent in interference limited conditions, but otherwise has a relatively poor spectrum utilization. TDMA, on the other hand has an excellent performance in conditions of low interference and noise.

A major advantage of CDMA, which is exploited by the MDMA protocol, is the possibility of temporary system overload by means of "graceful" degradation of the received signal quality. In the CDMA system, other transmissions appear as noise on the wanted signal. The limit to the number of CDMA channels is normally set by the level of allowable noise on the signal in order to achieve a required bit error rate. If this bit error rate performance can be sacrificed, then the level of noise can be allowed to rise, and hence the number of CDMA channels can be allowed to increase. In a TDMA system the maximum number of transmissions is fixed at the outset by the number of time slots per time frame.

<u>Access Protocols.</u> Both TDMA and CDMA split the single shared channel into "MDMA channels" which are used between connected pairs of subscribers. Although at this physical layer, the network is synchronous, as far as transmission of the bits is concerned, it is quite possible to operate both synchronous or asynchronous communication services depending on whether other layers of the protocol exist. The next layer up from the physical layer is the data-link layer. At this level the protocol may take the bits which

are being transmitted over the MDMA channel and packetise them. The advantage of this is that many data services require this form of data transmission because this protocol allows packets of data which have become corrupted during transmission to be retransmitted. This type of protocol is well known. Even at the physical level it is necessary to establish some form of protocol for users to access the common channel (i.e. to set up their MDMA channel) and to hand back the MDMA channel when the transmission has ended. Many different protocols have been developed to allow connection of a terminal to a network. All are based on the concept of the prospective user requesting access to the network and being granted access (or denied access) by the network controller. This sets a "flag" on the channel whilst that link is connected which is released when the user terminates the transmission. In multiple access networks, the protocol is made more complex by the need to arbitrate against access contention problems, which occurs when two users wish to gain access to the network simultaneously. The proposed protocol draws on these ideas, but differs in that a) it is applied to the new multiplexing method (MDMA), b) uses common channel signalling to control the operation of the network), c) certain aspects of the access protocol are entirely new.

<u>The Position of MDMA relative to CDMA and TDMA</u>

The new multiple access protocol MDMA has features of both TDMA and CDMA as far as message multiplexing goes but by means of a unique network access and control protocol MDMA is able to operate as a multiple access network. MDMA selects the best features of both systems to create a network architecture at the physical layer level which is vastly superior to either system. The CDMA method of multiplexing has very severe limitations in the multiple-access environment when two transmitters attempt to communicate with a single receiver and a collision occurs. The reason for this is that the CDMA protocol does not contain any media access protocols. Additionally, CDMA

generally requires a very large code set whereas MDMA does not. TDMA has the major restriction that if the network is not fully utilized, there are redundant time slots, and this is not particularly efficient. MDMA as implemented in the preferred example makes use of a protocol which enables dynamic allocation of the time slots, and is considerably more efficient that TDMA. Finally MDMA exploits the "graceful degradation" attribute of CDMA which allows temporary overload of the network.

In the following section the operation of the multiple access network using the MDMA protocol is described in greater detail.

Each subscriber gains access to the common radio channel via a broadband radio transceiver called a subscriber access device or SAD. This device is connected to the subscriber's data terminal equipment and it operates in full duplex mode. All transmissions from the SAD over the common radio channel are made via the access node, which is a radio base-station. The SADs communicate with the access nodes using spread-spectrum signalling but the effective data transmission is not necessarily time contiguous but restricted to occurring in a data sampled mode over a synchronized time slot within a fixed frequency time frame. The overall system operates as a synchronous communication channel, synchronized by the transmission from the access node.

The access node transmits continuously on the down link to all SADs using a specific pseudo-random code known to all SADs. We refer to this specific pattern of bits as a pilot code. By means of this continuous pilot code transmission, all SADs are able to synchronize their pseudo-noise code generators to this code. Synchronization is achieved using conventional code synchronization circuitry and delay-lock tracking loops. The time frame and slot periods are also synchronized to the code period. Consequently, all SADs are able to ensure that they are fully synchronized to the access node simply by

synchronising to the pilot code. Synchronization of the system is carried out under the control of a microprocessor in each SAD.

The access node constantly monitors the up-link from the SADs for transmissions. These transmissions from the SADs also use the pilot code. This code is reserved specifically for the SADs to gain access to the network, and is analogous in function to a hailing channel in a normal radio system.

In the first instance of switching on and programming a SAD, the SAD first achieves synchronization to the down-link pilot code. The SAD is programmed using a "smartcard" and this provides the SAD with a user identification number. The protocol for logging on to the network is as follows. The fully synchronized SAD monitors the up-link for activity and then hails the access node using the pilot code if and only if it senses that no other SAD is using the up-link pilot channel. This partially overcomes the contention problem when two users wish to gain access to the network. The method of signalling is to use either modulo 2 addition of the pseudo-noise pilot code onto the data or linear multiplication using a double balanced modulator. The method of modulation of this encoded data onto the carrier is arbitrary but is usually binary phase shift keying, quaternary phase shift keying or minimum phase shift keying.

The various data transmissions by the SAD on the up-link hailing channel and the access node on the down-link hailing channel to initiate SAD log-on to the network are described by the following handshake protocol:

SAD REQUEST	(up-link hailing)
BS ACKNOWLEDGEMENT	(down-link hailing)
SAD CHANNEL ACKNOWLEDGEMENT	(up-link hailing)

SAD REQUEST requires the following information to be sent:

i) the calling SADs identification number (which may give details of the physical location of the SAD for delay management purposes or which may point

to such information in the base-station's database)

ii) the caller's identification number (for security and billing)

iii) the service identification number (e.g., voice video, fax, data)

vi) type of request (e.g. regular call or network management function)

v) receiver's identification number (id).

In the case of the log-on request, this is identified in the "type of request" and no data is expected for the service identification number or the receiver id.

BS ACKNOWLEDGEMENT

The base-station access node acknowledges the SAD's request to log-on to the network, if it has been correctly decoded, with the following sequence:

i) SAD identification number

ii) service identification number

iii) request granted flag.

The log-on request may or may not be granted for many reasons (subscription cancelled etc). If no acknowledgement is sent to the SAD after a time-out period, bus contention is assumed and the SAD repeats the request.

To ensure that the network does not hang-up, the SAD must acknowledge receipt of the BS ACKNOWLEDGEMENT.

SAD CHANNEL ACKNOWLEDGEMENT

The following information is sent back to the access node:

i) SAD identification number

ii) caller's identification number

iii) service identification number

iv) BS Acknowledgement received flag.

If this acknowledgement is not received by the base-station, the base-station re-issues the BS ACKNOWLEDGEMENT message until SAD CHANNEL ACKNOWLEDGEMENT is received (within a time-out period). The SAD is then logged-on to the network.

If, during this process a second SAD attempts to use the up-link pilot channel simultaneously, the access node detects the collision, and makes no acknowledgement to either SAD and they both "time-out" and retransmit after a random delay in a similar manner to the ethernet access protocol. The SAD cannot transmit data to other SADs until the log-on process has been accomplished.

When the SAD attempts to gain access to the channel to transmit data to another SAD on the same network, the following protocol is followed. First, the SAD monitors the down-link pilot channel for activity. If none is detected, the SAD's address is sent to the access node on the pilot channel along with the address of the receiving SAD and the type of service the SAD wishes to transmit (eg voice, data, video). The access node checks to ensure that the addresses have been logged-on to the network, by reference to its database of logged-on subscribers, and replies to the calling SAD on the down-link using the pilot code if this is not the case and the attempted access fails. If both SADs have valid user identification numbers, the access node then checks whether the requested receiver SAD is engaged. If not, the SAD then checks to see if there are any free time slots and any free codes of total bandwidth which matches the requirements of the transmitting SAD.

If sufficient capacity exists, the access node acknowledges the original request for access by returning the user identification code and then, in order to free the pilot channel for other requests to access the channel, directs both the calling and receiving SADs to use a different CDMA code. This is accomplished by the access node which allocates a spare pseudo-random code to both SADs. The allocation of the code is in the form of an address which is transmitted to both SADs on the down-link pilot channel which points to a location inside the read only memory(ROM) of the SADs. This address contains the parameters needed for the SAD to generate the correct code.

This comprises an indication of the shift register tap points of the pseudo-noise code generator, which is a well understood technique. The "tap points" data is loaded into a mask which controls the feedback connections of the code generator. Every SAD contains information about every possible code within the code set and this is stored in read only memory (ROM). The information regarding a specific randomly chosen code is found at a specific address in the ROM.

In addition to the information regarding the code the access node sends back a list of the time slots that have been allocated to the SAD. The same information is then passed on to the requested receiving SAD. In this way, a handshake protocol has been established between the two SADs via the access node. It is possible for the handshake to be fully interlocked by relying on the two SADs to acknowledge that the information regarding the time slots has been received correctly. This can be done by transmitting using the new code allocation and time slot allocation to send an acknowledgement message, which is monitored temporarily by the access node.

Each SAD decodes the time slot information sent from the access node. This is simply a bit map of the time slots within the time frame which have been allocated to the two SADs. A microprocessor decoder analyses this information for contiguous time slots and if these are found modifies the header code in the "data protocol". Because the access protocol is largely independent of the data format used by the DTE there would be literally dozens of different frame structures for the different types of data which can be transmitted.

The SAD accesses the network using the following handshake protocol:

SAD REQUEST	(up-link hailing)
BS ACKNOWLEDGEMENT	(down-link hailing)
BS CHANNEL SELECT	(down-link) combined action
SAD CHANNEL ACKNOWLEDGEMENT	((up-link hailing)

INITIATE CALL ON SPECIFIED CHANNEL	(selected up/down link channel)
SAD CALL TERMINATE	(up-link hailing)
BS ACKNOWLEDGE TERMINATION	(down-link hailing)
BS DEALLOCATE CHANNEL	

SAD REQUEST requires the following information to be sent:

i) the calling SADs identification number (which may give details of the physical location of the SAD for delay management purposes or which may point to such information in the base-station's database)

ii) the caller's identification number (for security and billing)

iii) the service identification number (e.g. voice video, fax, data). This determines the number of time slots or CDMA channels required by the SAD

vi) type of request (e.g. regular call or network management function)

v) receiver's id.

BS ACKNOWLEDGEMENT

The base-station acknowledges the SAD request, if it has been correctly decoded, and then attempts to set up the call. It can also give BS CHANNEL SELECT information. The following information is sent on the down-link hailing channel:

i) SAD identification number

ii) service identification number

iii) request granted flag

iv) CDMA channel mask (a 4 or 5 bit mask identifying the number of CDMA channels allocated to this request)

v) TDMA time slot mask (a 6 bit mask identifying how many and which time slots have been allocated to this request).

The request may or may not be granted. If no acknowledgment is sent to the SAD after a time-out, bus contention is assumed and the SAD repeats the request.

To ensure that the network does not hang-up, the SAD must acknowledge receipt of the BS ACKNOWLEDGEMENT because the base-station has allocated a channel at this stage.

SAD CHANNEL ACKNOWLEDGEMENT

The following information is sent:

i) SAD identification number
ii) caller's identification number
iii) service identification number
iv) BS Acknowledgement received flag.

If this acknowledgement is not received by the base-station, the base-station re-issues the BS ACKNOWLEDGEMENT message until SAD CHANNEL ACKNOWLEDGEMENT is received (within a time-out period). The SAD then moves to the indicated channel and the call is set up.

SAD CALL TERMINATE

The following information is sent

i) SAD identification number
ii) caller's identification number
iii) service identification number
iv) call terminate flag.

BS ACKNOWLEDGE TERMINATION

Following information sent:

i) SAD identification number
ii) service identification number
iii) BS Acknowledge termination flag

If the SAD does not receive a BS ACKNOWLEDGE TERMINATION flag, the SAD CALL TERMINATE is sent again until the flag is true.

At this stage, the base-station deallocates the channels to the SAD.

When the base-station attempts to set-up a call with a SAD the following protocol is observed:

BS REQUEST (down-link hailing)
SAD ACKNOWLEDGEMENT (up-link-link hailing)

BS CHANNEL SELECT	(down-link hailing)
SAD CHANNEL ACKNOWLEDGEMENT	(up-link hailing)
INITIATE CALL ON SPECIFIED CHANNEL	(selected up/dow link channel)
SAD CALL TERMINATE	(up-link hailing)
BS ACKNOWLEDGE TERMINATION	(down-link hailing)
BS DEALLOCATE CHANNEL	

The BS REQUEST is a call put out on the down-link hailing channel to a specific SAD. The following information must be sent:

i) SAD identification number
ii) receiver's identification number
iii) request for SAD to receiver
iv) service identification number
v) caller's identification number
vi) service type required.

The request may fail because the SAD may not be able to satisfy iii) (because it is busy) or v) (because it cannot provide the necessary terminal equipment for the required service).

This is acknowledged by SAD ACKNOWLEDGEMENT, which sends the following information:

i) SAD identification number
ii) receiver identification number
iii) service identification number
iv) receive acknowledge flag (yes/no).

If the BS receives a valid NO flag, the call is terminated and appropriate messages (described earlier) are sent to the caller. If the BS receives a valid YES flag, the BS sends a BS CHANNEL SELECT message. If the BS receives no valid signal it re-issues the BS REQUEST message repeatedly until a time-out has been exceeded whereupon the call set-up is deemed to have failed. Note that for the down-link there are no contention problems because the base-station controls the hailing channel.

BS CHANNEL SELECT requires the following information to be sent:

i) SAD identification number
ii) receiver's identification number
iii) service identification number
iv) CDMA mask
v) TDMA mask.

The base-station waits for a SAD ACKNOWLEDGEMENT to be sent and repeats the BS CHANNEL SELECT until it is received (or until time-out).

The call is then connected.

The SAD can issue a SAD CALL TERMINATE message which requires a BS ACKNOWLEDGE TERMINATION message to complete the action.

A feature of the MDMA protocol is dynamic allocation of time-slots and dynamic allocation of CDMA channels.

This is possible if the protocols referred to above are modified so that in place of some generic command "INITIATE CALL ON SPECIFIED CHANNEL" a more specific protocol command such as SEND (or RECEIVE) PACKET is issued. In this case whenever a trailer byte is detected, indicating the end of a packet the down-link hailing channel can be probed for CHANNEL TRANSFER.

This message sends the following information.

i) SAD identification number
ii) receiver's identification number
iii) service identification number
iv) new TDMA mask
v) new CDMA mask.

Before the new channels are set up, it is necessary for the SAD to issue a CHANNEL TRANSFER ACKNOWLEDGEMENT.

Finally, if the SAD is switched off or the smartcard is removed the SAD issues a log-off dialogue with the access node before powering-down. The protocol for the log-off is as follows:

SAD REQUEST
BS ACKNOWLEDGEMENT

SAD CHANNEL ACKNOWLEDGEMENT

In this case the SAD sends a log-off request on the hailing channel. This is acknowledged by the access node and the SAD acknowledges the base-station acknowledgement. If neither acknowledgement is received retransmission of the request takes place.

Figure 5 shows a typical frame structure of the MDMA protocol. In this diagram are shown Y CDMA channels each sub-divided into X contiguous time-slots. One of these CDMA channels represents the hailing channel (e.g. CDMA channel 0). After X time slots there is a inter-frame gap or guard-band time. This delineates the frame periods and represents the worst-case propagation delay from the furthest SAD to the access node. Note how only the hailing channel transmits in the inter-frame gap.

In the preferred method, the duration of the time slot is selected to allow 55 bytes of data to be transmitted (corresponding to a modified ATM packet of data) at a rate of 1.2 Mb/s and the frame rate is selected so that the lowest data rate per MDMA channel is 16 kb/s. However, this particular frame structure is only typical of the preferred frame structure, which could have different timings.

Possible ISDN Services	
Service	**Bandwidth**
Telephone	16 - 64 kb/s
Alarms	100 b/s
Utility Metering	100 b/s
Energy Management	100 b/s
Videotex	2.4 - 64 kb/s
Electronic Mail	4.8 - 64 kb/s
Facsimile	4.8 - 64 kb/s
Slow Scan TV	56 - 64 kb/s
Video Conferencing	128 - 1024 kb/s

Table 1 Typical Services which can be accessed via the proposed multiple access system.

CLAIMS

1. A communication system characterised by subscriber channels defined by the combination of a selected direct sequence CDMA code and a selected one or more time slots within a TDMA frame.

2. A system according to claim 1, the system including a plurality of subscribers (2) connected via a common transmission medium to an access node (1) arranged to assign the channels to the subscribers during an access phase.

3. A system according to claim 2, in which the access node (1) is arranged to communicate with the different subscribers (2) on a common hailing channel assigned a direct sequence CDMA pilot code.

4. A communication system including an access node arranged to communicate with a plurality of subscribers characterised by subscriber channels defined by the combination of a CDMA code and a selected one or more time slots within a TDMA frame and in that the access node is arranged to communicate with the different subscribers on a common hailing channel defined by a pilot CDMA code common to the node and the subscribers.

5. A system according to claim 2, 3, or 4, in which the node (1) is arranged to select a free channel and to transmit to the transmitting and receiving subscribers (2) an indication of the selected channel.

6. A system according to claim 5, in which the node (1) is arranged to communicate in addition data indicating a selected data format for the transmissions between the subscribers, the said data indicating whether the channel includes single or multiple time slots within each frame, and where multiple time slots are used whether those slots are contiguous or time disjoint.

7. A system according to claim 6, in which the node (1) is arranged to adapt the data format when the channel includes a plurality of contiguous time slots by replacing

redundant header or trailer bits in the second or subsequent slots with traffic data.

8. A method of operating a communication system characterised by allocating to subscribers channels defined by the combination of a selected direct sequence CDMA code and a selected one or more time slots within a TDMA frame.

9. A method according to claim 8, in which the communication system comprises a plurality of subscribers (2) connected via a common transmission medium to an access node (1) and in which the step of allocating subscriber channels is carried out by the access node.

10. A method according to claim 9, in which the node (1) communicates with different subscribers (2) on a common hailing channel assigned a direct sequence CDMA pilot code.

11. A method of operating a communication system including an access node, and a plurality of subscribers arranged to communicate via the access node, characterised by assigning to the subscribers channels defined by the combination of a CDMA code and a selected one or more time slots within a TDMA frame and communicating between the access node and different subscribers during an access phase on a hailing channel defined by a pilot CDMA code common to the node and to the subscribers.

12. A method according to claim 10 or 11, in which, in an access phase, after the node (1) has communicated with a transmitting subscriber and a receiving subscriber on the common hailing channel, the node selects a free channel defined by a CDMA code other than the pilot code, and a selected one or more time slots, and transmits to the said subscribers an indication of the selected channel, the subscribers subsequently communicating via the node on the selected channel.

13. A method according to claim 12, in which the node (1) is arranged to communicate in addition data indicating a selected data format for the transmissions between the said subscribers, the said data indicating whether the channel includes single or multiple time slots within each time

frame, and where multiple time slots are used, whether those slots are contiguous or time disjoint.

14. A method according to claim 13, in which the node (1) adapts the data format when the channel includes a plurality of contiguous time slots, by replacing redundant header or trailer bits in the second or subsequent slots with traffic data.

15. A system according to claim 4, or any one of claims 5 to 7 when dependent on claim 4, in which the CDMA code is a frequency hopping code arranged to modulate the frequency of a carrier signal.

16. A method according to claim 11, or any one of claims 12 to 14 when dependent on claim 11, in which the CDMA code is a frequency hopping code arranged to modulate the frequency of a carrier signal.

17. A system according to any one of claims 1 to 7 and 15, or method according to any one of claims 8 to 13 and 16, in which the system is a digital radio network.

18. A subscriber access device adapted for use in a system, or by a method according to any one of the preceding claims.

19. A subscriber access device according to claim 18, in which the device is a radio telephone.

20. An access node (1) adapted for use in a system according to any one of the preceding claims.

21. A method of operating a communication system including the step of allocating TDMA channels to subscribers, characterised by the step of adapting the data format of the channel when the channel includes a plurality of contiguous time slots by replacing redundant header or trailer bits in the second or subsequent slots with traffic data.

Fig.1.

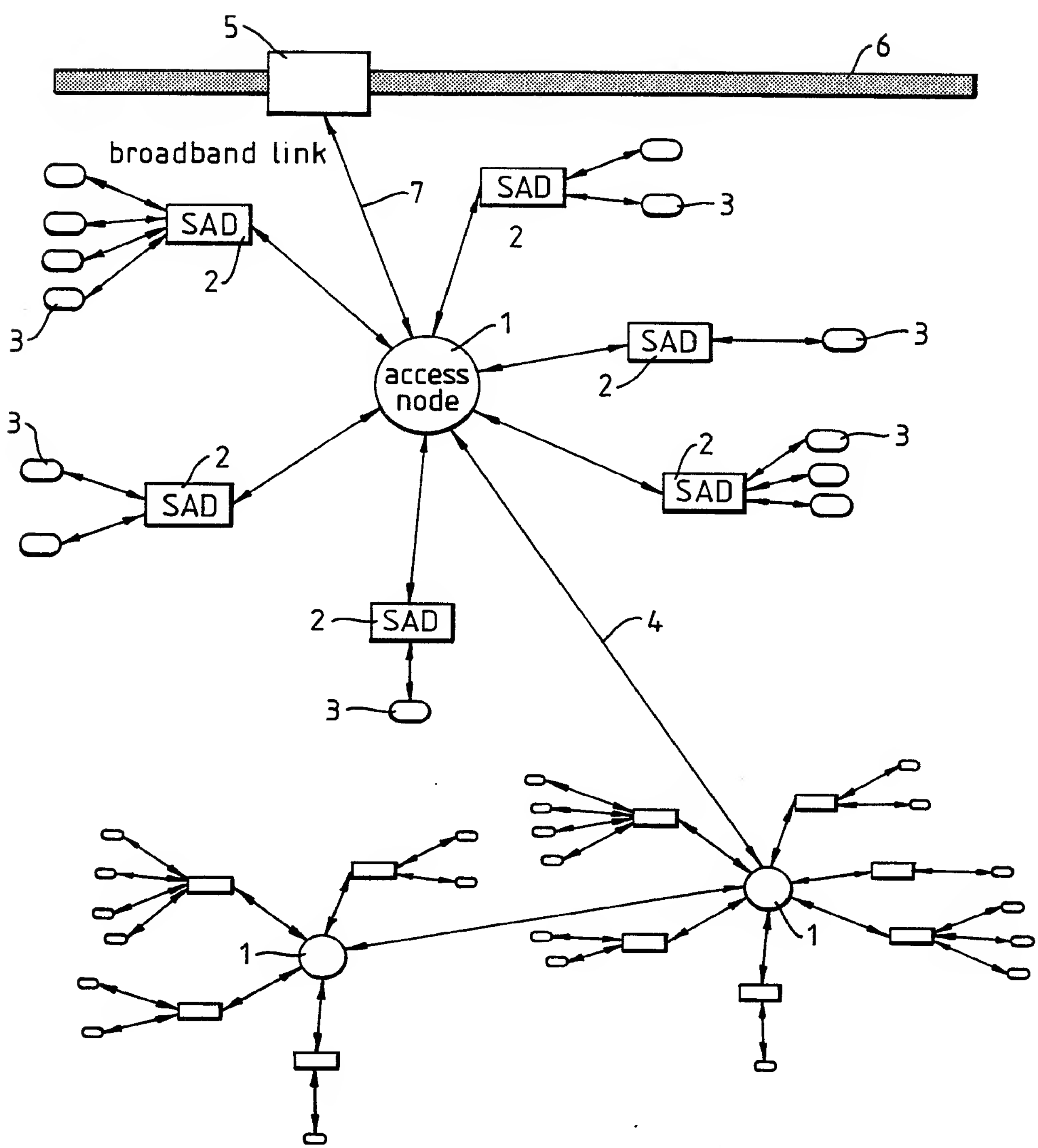

5
6
broadband link
7
SAD
SAD
SAD
SAD
SAD
SAD
2
2
2
2
2
2
3
3
3
3
3
3
1
access node
4
1
1

Fig.2b.

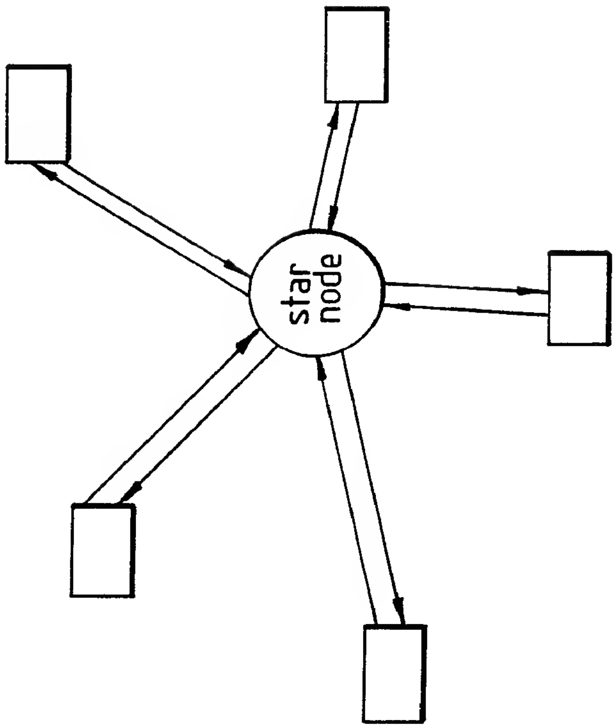


Fig.2a.

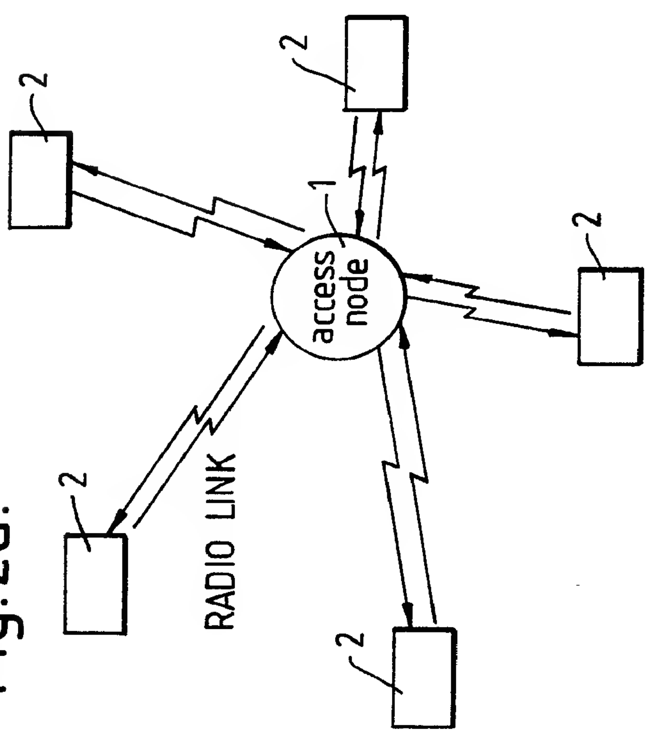


Fig.3a.

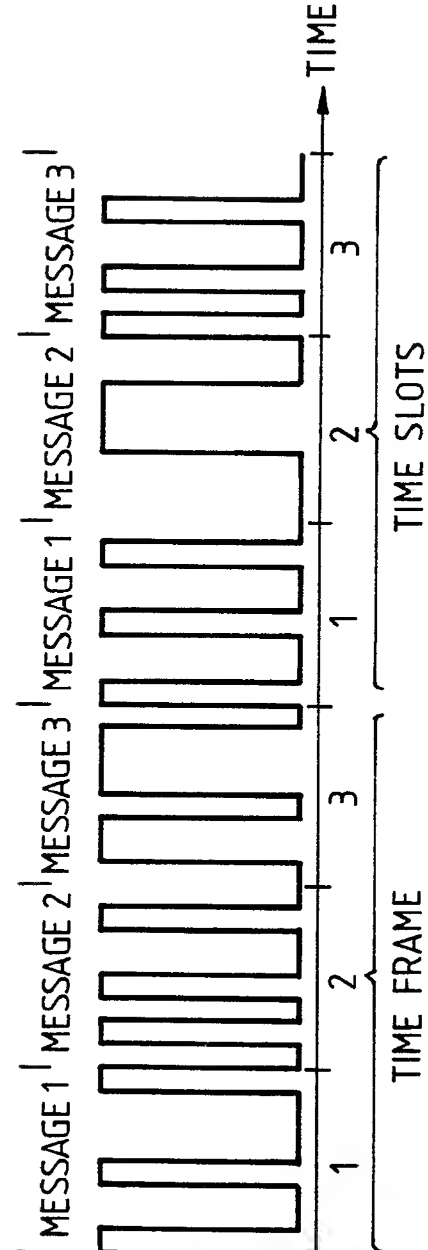


Fig. 3b.

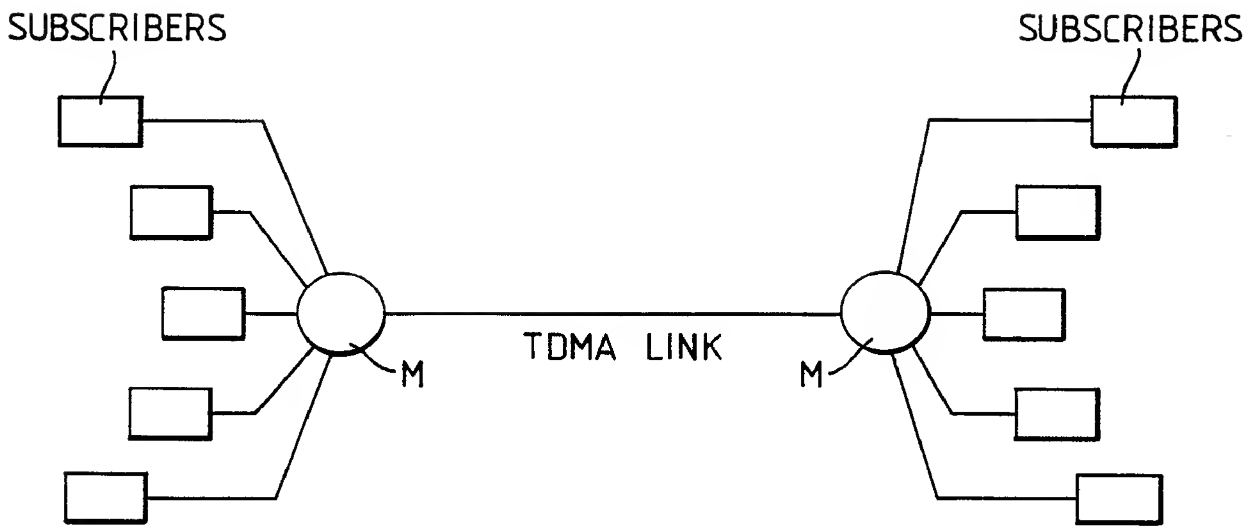

SUBSCRIBERS
SUBSCRIBERS
TDMA LINK
M
M

Fig. 3c.

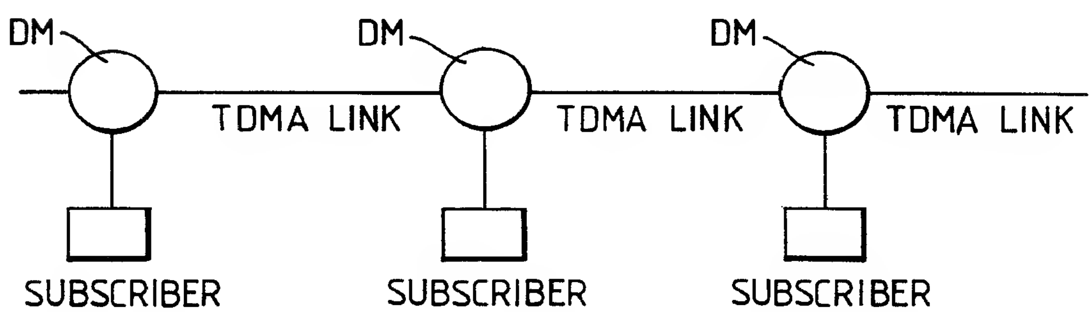

DM
DM
DM
TDMA LINK
TDMA LINK
TDMA LINK
SUBSCRIBER
SUBSCRIBER
SUBSCRIBER

Fig.4a.

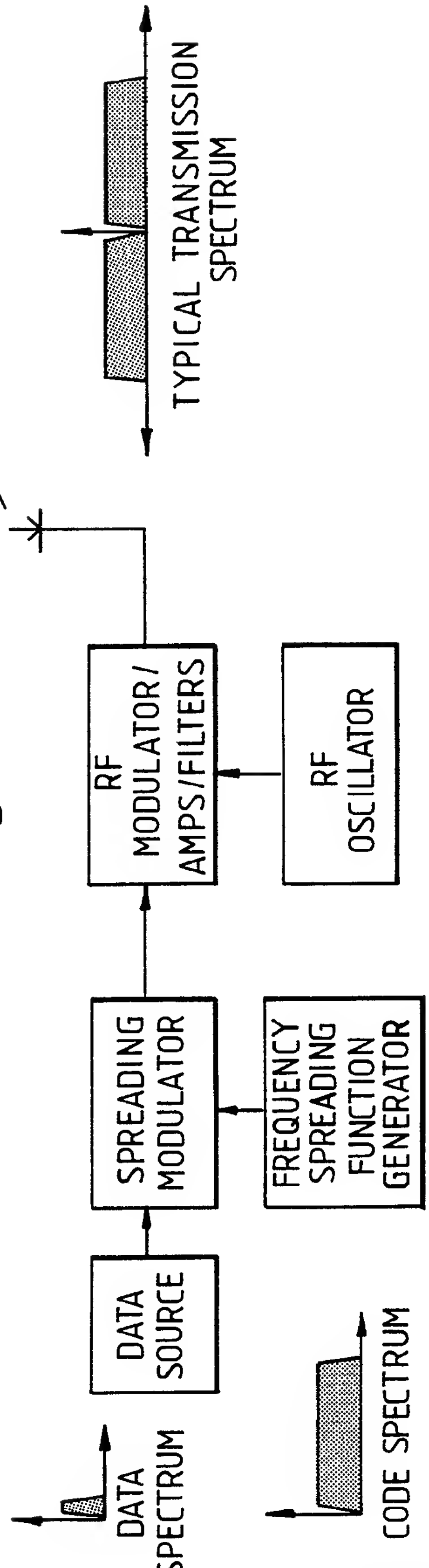

DATA SPECTRUM
DATA SOURCE
CODE SPECTRUM
SPREADING MODULATOR
FREQUENCY SPREADING FUNCTION GENERATOR
RF MODULATOR/ AMPS/FILTERS
RF OSCILLATOR
TYPICAL TRANSMISSION SPECTRUM

Fig.4b.

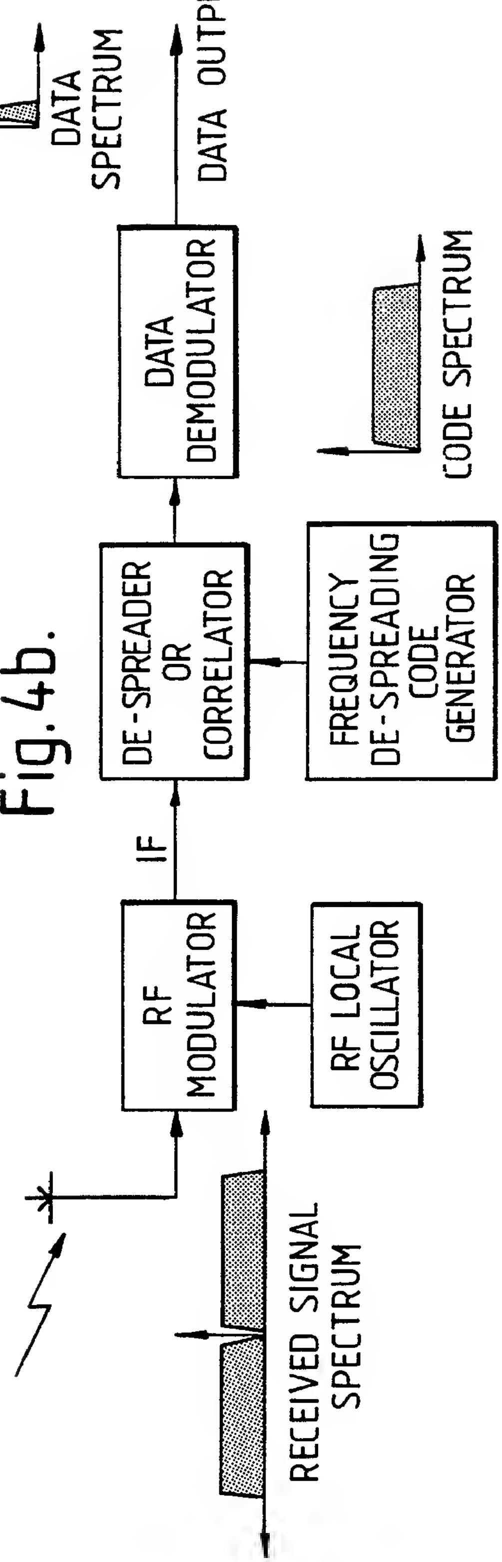

RECEIVED SIGNAL SPECTRUM
RF MODULATOR
RF LOCAL OSCILLATOR
IF
DE-SPREADER OR CORRELATOR
FREQUENCY DE-SPREADING CODE GENERATOR
DATA DEMODULATOR
CODE SPECTRUM
DATA OUTPUT
DATA SPECTRUM

Fig.5.

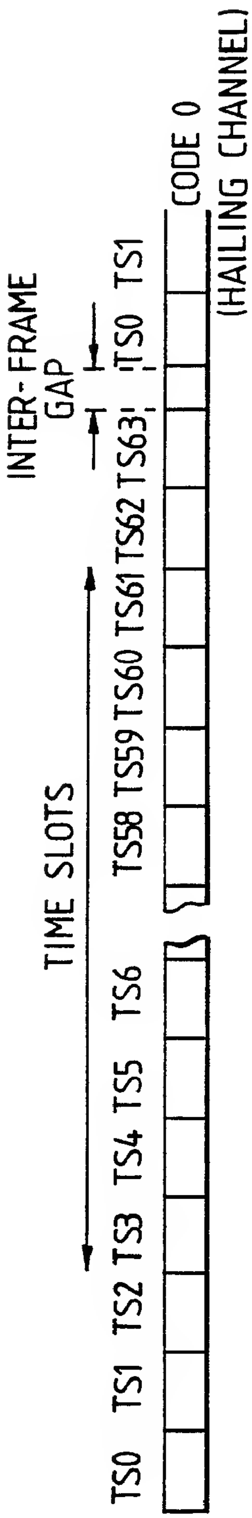

TIME SLOTS
INTER-FRAME GAP
TS0 TS1 TS2 TS3 TS4 TS5 TS6 TS58 TS59 TS60 TS61 TS62 TS63 TS0 TS1
CODE 0 (HAILING CHANNEL)
CODE 1
CODE 2
CODE X-2
CODE X-1
CODE X

Fig.5a.

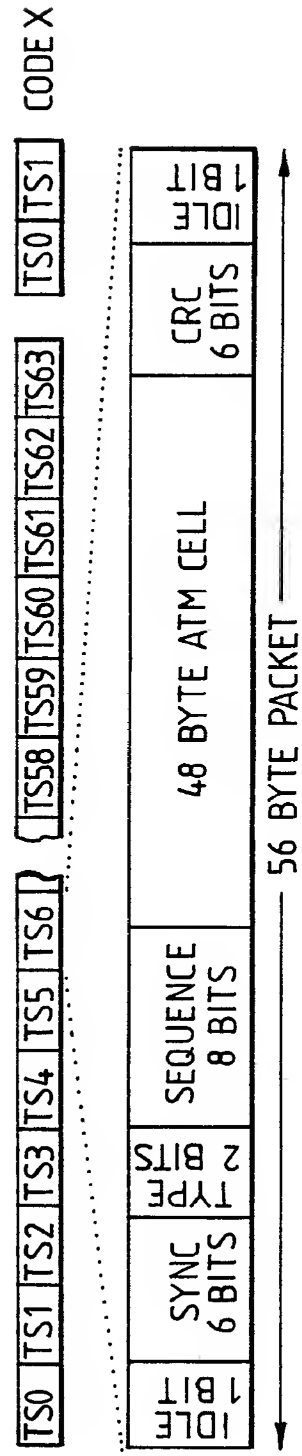
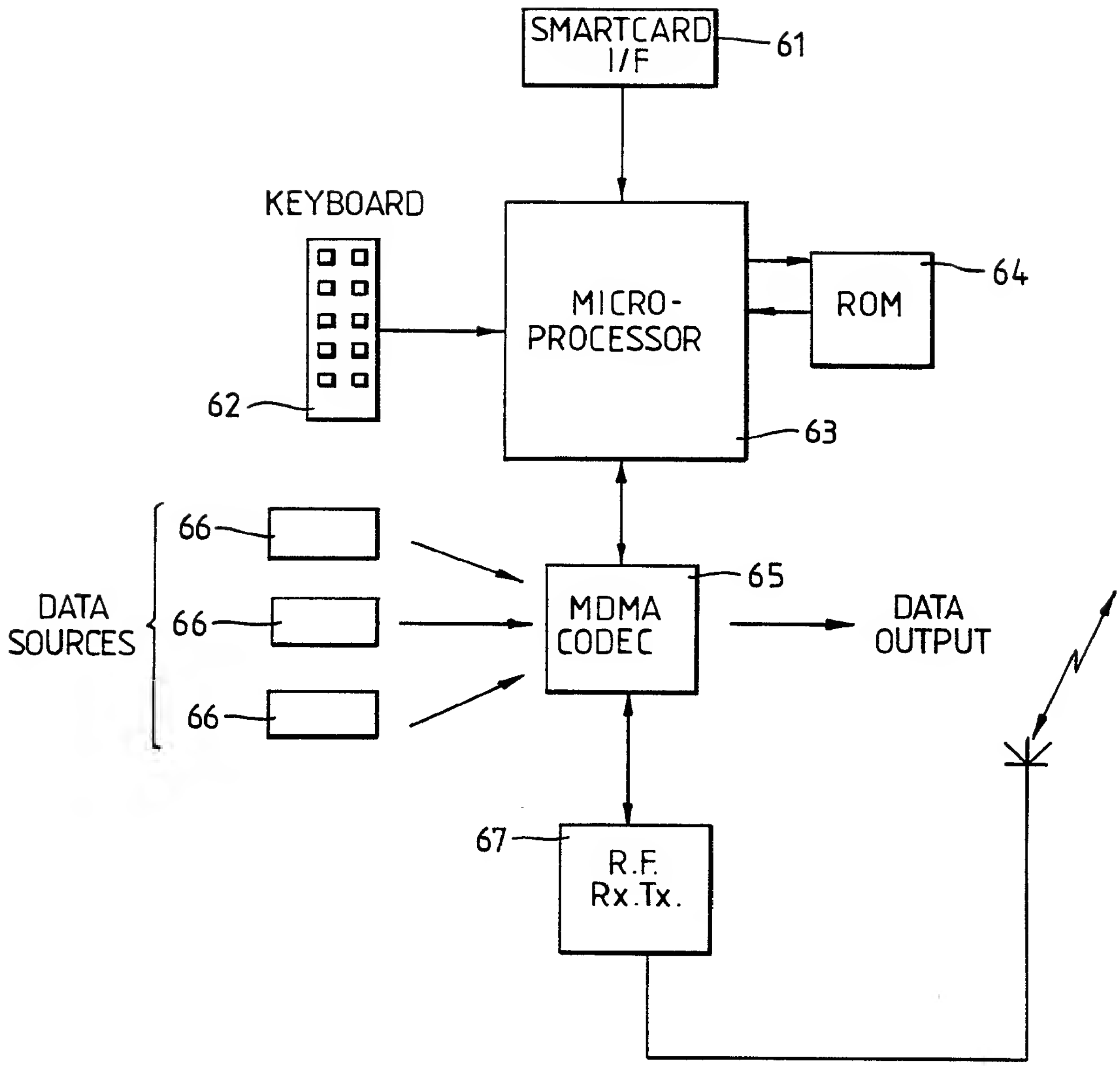

CODE X
TS0 TS1 TS2 TS3 TS4 TS5 TS6 TS58 TS59 TS60 TS61 TS62 TS63 TS0 TS1
IDLE 1 BIT
SYNC 6 BITS
TYPE 2 BITS
SEQUENCE 8 BITS
48 BYTE ATM CELL
CRC 6 BITS
IDLE 1 BIT
56 BYTE PACKET

Fig.6.


SMARTCARD I/F
61
KEYBOARD
MICRO-PROCESSOR
ROM
64
62
63
66
66
66
DATA SOURCES
MDMA CODEC
65
DATA OUTPUT
67
R.F. Rx.Tx.

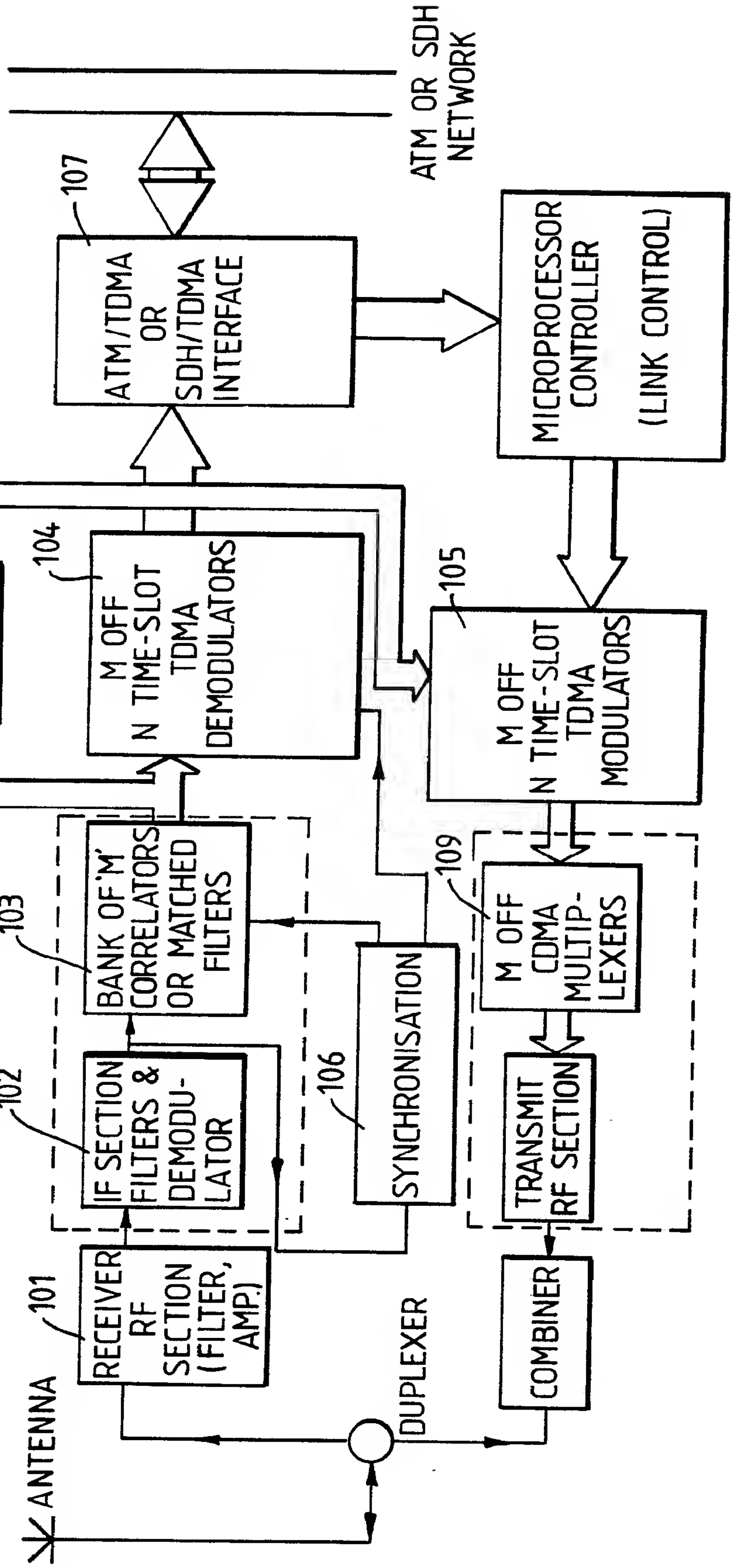

ATM OR SDH NETWORK
107
ATM/TDMA OR SDH/TDMA INTERFACE
MICROPROCESSOR CONTROLLER (LINK CONTROL)
108
POWER CONTROL MODULE
104
M OFF N TIME-SLOT TDMA DEMODULATORS
105
M OFF N TIME-SLOT TDMA MODULATORS
103
BANK OF 'M' CORRELATORS OR MATCHED FILTERS
109
M OFF CDMA MULTIP-LEXERS
102
IF SECTION FILTERS & DEMODU-LATOR
106
SYNCHRONISATION
TRANSMIT RF SECTION
101
RECEIVER RF SECTION (FILTER, AMP.)
DUPLEXER
COMBINER
ANTENNA

Fig. 7.

INTERNATIONAL SEARCH REPORT

International Application No PCT/GB 93/00199

I. CLASSIFICATION OF SUBJECT MATTER (if several classification symbols apply, indicate all)[6]

According to International Patent Classification (IPC) or to both National Classification and IPC

Int.Cl. 5 H04J13/00

II. FIELDS SEARCHED

Minimum Documentation Searched[7]

Classification System	Classification Symbols
Int.Cl. 5	H04J ; H04B ; H04Q ; H04L

Documentation Searched other than Minimum Documentatioo to the Extent that such Documents are Included in the Fields Searched[8]

III. DOCUMENTS CONSIDERED TO BE RELEVANT[9]

Category °	Citation of Document, [11] with indication, where appropriate, of the relevant passages [12]	Relevant to Claim No.[13]
X	EP,A,0 210 698 (PHILIPS) 4 February 1987 see column 3, line 5 - line 53 see column 4, line 9 - column 6, line 26 see column 7, line 16 - line 45 see column 7, line 53 - column 8, line 18	1-5, 8-12, 15-20
Y	see column 11, line 29 - line 45; claims 1,2; figures 1,2 ---	6,7,13, 14
X	EP,A,0 211 460 (PHILIPS) 25 February 1987 see column 5, line 32 - column 6, line 55 see column 8, line 11 - line 40 see column 8, line 49 - column 9, line 13	1-5, 8-12, 15-20
A	see column 9, line 52 - column 10, line 1	6,7,13
A	see column 13, line 12 - line 38; figure 1 ---	14

-/--

° Special categories of cited documents : [10]

"A" document defining the general state of the art which is not considered to be of particular relevance

"E" earlier document but published on or after the international filing date

"L" document which may throw doubts on priority claim(s) or which is cited to establish the publication date of another citation or other special reason (as specified)

"O" document referring to an oral disclosure, use, exhibition or other means

"P" document published prior to the international filing date but later than the priority date claimed

"T" later document published after the international filing date or priority date and not in conflict with the application but cited to uoderstand the principle or theory underlying the inventioo

"X" document of particular relevance; the claimed invention canoot be considered novel or cannot be considered to iovolve an inventive step

"Y" document of particular relevance; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documeots, such combination being obvious to a person skilled in the art.

"&" documeot member of the same patent family

IV. CERTIFICATION

1

Date of the Actual Completion of the International Search	Date of Mailiog of this International Search Report
28 APRIL 1993	11.05.93
International Searching Authority	**Signature of Authorized Officer**
EUROPEAN PATENT OFFICE	PIEPER T.

III. DOCUMENTS CONSIDERED TO BE RELEVANT (CONTINUED FROM THE SECOND SHEET)

Category °	Citation of Document, with indication, where appropriate, of the relevant passages	Relevant to Claim No.
X	EP,A,0 412 583 (MOTOROLA) 13 February 1991 see column 2, line 13 - line 40 see column 4, line 27 - column 5, line 19	21
Y	see column 6, line 5 - line 15; figures 1,2,3A	6,7,13, 14
A	IEEE TRANSACTIONS ON COMMUNICATIONS vol. 27, no. 8, August 1979, NEW YORK US pages 1153 - 1160 G. J. COVIELLO 'Comparative Discussion of Circuit- vs. Packet-Switched Voice' see page 1153, left column, line 15 - line 28 see page 1158, right column, line 16 - page 1159, left column, line 24; figure 10	7,14
A	IEEE TRANSACTIONS ON VEHICULAR TECHNOLOGY vol. 33, no. 8, August 1984, NEW YORK US pages 179 - 190 D. VERHULST ET AL. 'Slow Frequency Hopping Multiple Access for Digital Cellular Radiotelephone' see page 180, left column, paragraph 2 - page 181, left column, paragraph 3	15,16
A	41ST IEEE VEHICUALAR TECHNOLOGY CONFERENCE 19 May 1991, STJ. LOUIS , US pages 57 - 62 A. SALMASI ET AL. 'ON THE SYSTEM DESIGN ASPECTS OF CODE DIVISION MULTIPLE ACCESS (CDMA) APPLIED TO DIGITAL CELLULAR AND PERSONAL COMMUNICATIONS NETWORKS' see abstract see page 57, left column, paragraph 1 -paragraph 3 see page 57, right column, paragraph 5 see page 61, right column, paragraph 5	1-4, 8-11, 17-20
A	NATIONAL TELECOMMUNICATIONS CONFERENCE vol. 1, 1 December 1975, NEW ORLEANS , US pages 14-10 - 14-14 C.E. ELLINGSON 'JOINT TACTICAL INFORMATION SYSTEM (JTIDS)' see page 14-10, right column, paragraph 3 - page 14-11, left column, paragraph 4A see page 14-12, left column, paragraph 6 see page 14-13, left column, line 57 - line 66	1,4,6-8, 11,13, 14,17,19

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III. DOCUMENTS CONSIDERED TO BE RELEVANT (CONTINUED FROM THE SECOND SHEET)		
Category °	Citation of Document, with indication, where appropriate, of the relevant passages	Relevant to Claim No.
A	NTZ NACHRICHTENTECHNISCHE ZEITSCHRIFT vol. 27, no. 7, July 1974, BERLIN DE pages 253 - 259 W. HEROLD 'Ein Funktelephonsystem mit Codemultiplex' see page 253, right column, paragraph 1 -paragraph 3 see page 257, right column, paragraph 2 - page 258, left column, paragraph 1; figures 5,6	1-5, 8-12, 17-20
A	IEEE GLOBAL TELECOMMUNICATIONS CONFERENCE vol. 2, 27 November 1989, DALLAS , US pages 733 - 737 DE GAUDENZI ET AL. 'High Efficiency Voice Activated CDMA Mobile Communication System Based on Master Code Synchronization' see page 733, right column, line 16 - line 22 see page 734, left column, line 37 - line 50; figure 4	1-4,8-12
A	INTERNATIONAL SWITCHING SYMPOSIUM 1987 vol. 3, 15 March 1987, PHOENIX, US pages 759 - 765 P. ROBERT ET AL. 'ALCATEL LAND MOBILE SYSTEM CD900 A FULLY DIGITAL CELLULAR APPROACH USING WIDEBAND TDMA' see page 760, right column, paragraph 3.1 - page 761, right column, paragraph 3.2	6,7,13, 14

ANNEX TO THE INTERNATIONAL SEARCH REPORT ON INTERNATIONAL PATENT APPLICATION NO.

GB 9300199
SA 69537

This annex lists the patent family members relating to the patent documents cited in the above-mentioned international search report. The members are as contained in the European Patent Office EDP file on 28/04/93
The European Patent Office is in no way liable for these particulars which are merely given for the purpose of information.

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EP-A-0211460	25-02-87	DE-A- 3527331	05-02-87
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		AU-A- 5589086	20-10-87
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